National Aeronautics and Space Administration

science & sports

Educational Product	
Educators and Students	Grades 5-8

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National Content Standards

1. National Research Council
2. National Council of Teachers of Mathematics
3. International Technology and Engineering Education Association

	Hovering on a Cushion of Air	Center of All Things	Let's Do the Twist	Crazy Balloons	Javelin Rockets	Space Helmet Challenge
SCIENCE STANDARDS[1]						
Physical Science						
Motions and Forces						
• Understand motions and the forces that cause motion	⚽	⚽	⚽	⚽	⚽	⚽
Transfer of Energy						
• Understand ways in which energy is transferred	⚽		⚽	⚽	⚽	⚽
• Understand the relationship between energy and force						
Science and Technology						
• Abilities of Technological Design	⚽			⚽	⚽	⚽
• Design a solution to a problem and evaluate its effectiveness						
MATHEMATICS STANDARDS[2]						
Number and Operations						
• Perform operations with multi-digit whole numbers and with decimals to the hundredths	⚽				⚽	
Algebra						
• Write and interpret numerical expressions	⚽					
• Analyze patterns and relationships						
Geometry						
• Graph points on the coordinate plane to solve real-world and mathematical problems	⚽	⚽	⚽	⚽	⚽	⚽
• Classify two-dimensional figures into categories based on their properties						
• Solve real-world and mathematical problems involving area, surface area, and volume						
Measurement						
• Represent and interpret data	⚽	⚽	⚽		⚽	⚽
TECHNOLOGY STANDARDS[3]						
Design						
Standard 8. Students will develop an understanding of the attributes of design.	⚽			⚽	⚽	⚽
Standard 9. Students will develop an understanding of engineering design.	⚽			⚽	⚽	⚽
Standard 10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.	⚽			⚽	⚽	⚽

I Do the Shimmy When I Fly Through the Air Part Two

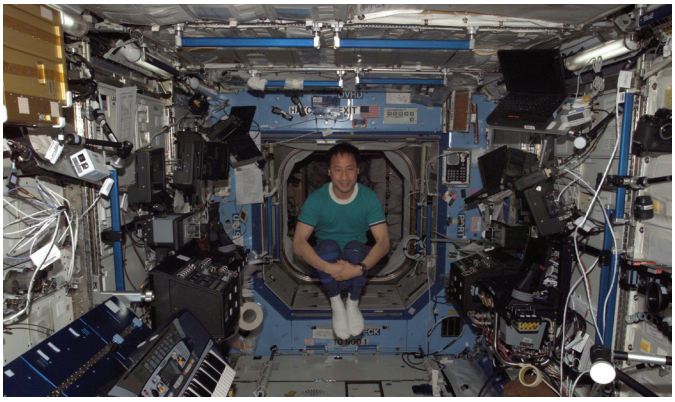
Half-time Talk Show

We all have a center of mass in our bodies. When snowboarders perform aerials, they rotate around their centers of mass. That's why a light on a snowboarder, performing in the dark, would inscribe a curved but smooth line. The snowboarder's tumbling body parts are just rotating around and following the center of mass down the half-pipe slope.

How then does the snowboarder achieve the intricate tricks? Again, it's a matter of science. While in the air, the snowboarder twists and turns body parts. The head is thrown back or forward, knees brought to the chest or extended, arms tucked in or shot out, the waist twisted (sometimes all this at the same time). These movements, driven by muscle power, cause the body to rotate around the center of mass.

Back to the balanced pencil. Using your other hand, give a sharp flick to one end of the pencil. The pencil will tumble end over end through the air but always rotate around the center of mass you located.

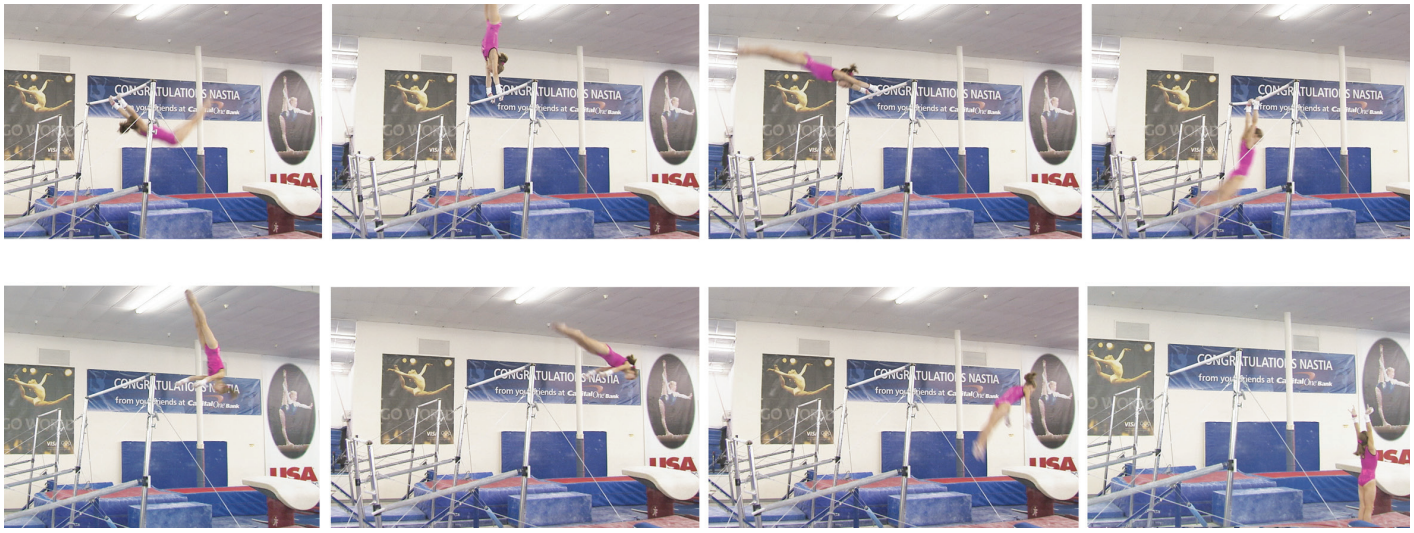
Even though a snowboarder's body is not rigid like a pencil, sharp body movements



Astronaut Ed Lu doing an "aerial" on the ISS.

on one side of the center of mass are balanced by sharp body movements on the other side. When the snowboarder finally stops twisting or tucking (so they can land their trick), the rotations stop, hopefully with the snowboard positioned beneath to land on the snow.

All the twists and turns in flight are governed by the snowboarder's moment of inertia. We've learned that inertia is the resistance of an object to change its motion (Newton's First Law). Moment of inertia is the law applied to rotating objects. When a snowboarder goes airborne, the muscle-driven body movements exert a force that causes rotation. How fast one rotates is determined



Unlike the astronaut on the ISS who has to push on a wall to start tumbling, the gymnast takes advantage of gravity to build up amazing speed as she rotates on the bar and prepares for a successful dismount.

by how tight the body is. When arms and legs are drawn into a tuck, the rotation is very fast. When they are spread out, the rotation slows or stops, depending on how quickly the movement takes place.

Moment of inertia is especially easy to see in another winter sport - figure skating. When skaters want to spin in place, they swing their extended arms to start the spin, then bring them into a tight hug. Legs come in, too. That speeds up the rotation rate. Extending the arm and legs out slows the spin.

A gymnast can achieve amazing rotational speed while tumbling in the air during floor exercises or dismounting from the parallel bars. Rotation speed increases as the body (mass) is tucked tighter, decreasing the axis of rotation.

Would you like to try spinning like an ice skater? The next activity, “Let’s Do The Twist,” will show you how - no skates required!

Let's Do the Twist

Objectives:
Students will:
- perform "aerials" on a swivel office chair
- investigate the principle of conserving angular momentum

Preparation:
Clear an area in your classroom so that volunteers on the chair will be able to sit with arms and legs extended and not hit any objects or fellow students.

Materials:
- Swivel office chair
- Two hand weights two or three pounds each
- Bearing platform (optional - see special instructions)
- Large plastic five-gallon hardware store bucket (optional)

Management Tips:
Select an office chair with a free-moving swivel. An adjustable artist stool will also work. It is important that it turns freely when spun. It is also best that the chair be set in a clear area on a hard, uncarpeted floor. When doing the second part of the activity, start slow to help students retain their balance.

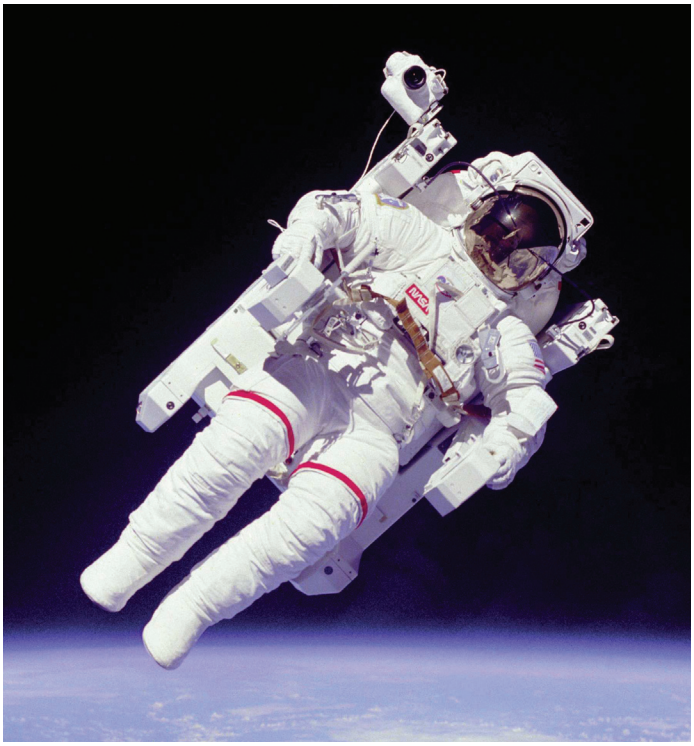
Procedure: Aerials on an office chair
1. Ask students if they have ever watched acrobatic-type sporting events in person or on TV. With student help, create a list of these events on the board. Acrobatic-type sporting events include those in which contestants perform maneuvers with their bodies, usually while airborne. The list might include:
   Snowboarding
   Platform diving
   Skateboarding
   Figure skating

   Gymnastics
   Trampoline
   Etc.

   Discuss what these events have in common. Ask if students think these events would work in the microgravity environment of space.
2. Select a volunteer for a demonstration. Place the volunteer on the swivel office chair and challenge him or her to try to move the chair across the room without touching the floor or any other object with their hands or feet. The student will be able to twist and rock and even turn the chair around but will not be able to move across the room. When the student stops moving, so will the chair.
3. Ask other students to make observations about the movements and the progress of crossing the floor.
4. If time permits, allow other students to demonstrate the activity.

Assessment:
Have students answer the questions on the activity sheet.

Discussion Questions:
Around what point is the student on the chair turning?
The student is turning around the combined



Astronaut Bruce McCandless flies the manned maneuvering unit during a 1983 spacewalk. The unit, resembling an easy chair, has posts above the shoulders and near the knees. Each contain clusters of gas jets for maneuvering in space.

center of mass of the chair and the student's body. The bearing of the chair tends to be close to this point and rotation occurs around it.

Why does the chair stay put?

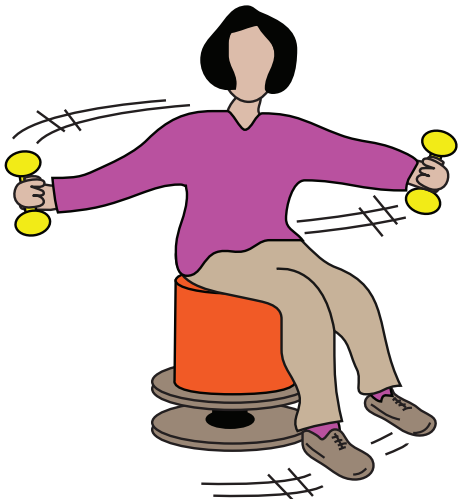
Because of the bearing beneath the chair seat and the casters on the chair feet, friction with the floor is very low. The volunteer is not able to exert a sufficient force on the floor to move across the room. Without an action/reaction force (Newton's Third Law of Motion), it is not possible to move across the floor. (Note: Sometimes, one or more chair casters are worn and "grab" the floor in some directions, causing small jerking movements that leads to small movements from the initial place. With all casters working well, the chair stays over the same place.)

What would happen to an astronaut on a spacewalk if the astronaut forgot to attach to the ISS and drifted out of reach of the structure?

The astronaut would be unable to get back to the station and become a separate "satellite" circling Earth.

Extensions:

- Ask students to design a piece of equipment that could be used to bring an astronaut back to the ISS should the astronaut get loose and be drifting in space. Have students diagram their ideas and explain them to the class.
- Have students create an Olympic acrobatic event for inside the ISS. How would the event be played, what equipment could be used, what aerials could be performed, how would points be scored, etc.?



Procedure: Conserving angular momentum (Note: This activity can be done with the same office chair used for the previous activity. However, many schools use bearing platforms available from science supply catalogs. These platforms spin more freely than office chairs, producing a better rotating effect. Refer to the next page for instructions on constructing a very smooth but rugged platform using an automotive bearing.)

1. Place a student on the swivel office chair or a bearing platform (with an upside-down bucket for a seat).
2. Give the student two hand weights, and tell the student to extend his or her arms.
3. Spin the student slowly. On command, have the student bring the two weights to his or her chest. The student's rotation rate will

dramatically increase. Tell the student to extend the weights again, and the rotation rate will decrease.

Assessment:

Discuss student observations of what happened when the weights were extended, brought inward, and extended again.

Discussion Question:

Does the spinning student speed up when the weights are brought inward? Explain.

No. Except for a minor slowing due to bearing friction, there wasn't any change in speed. Speed is the distance an object travels over a unit of time, such as meters per second. Instead, what did change was rotation rate, which is measured in revolutions per unit of time.

For discussion's sake, let's say that the weights, when extended, follow a circle that has a circumference of five meters. When the weights are brought inward, the circle has a circumference of one meter. Finally, let's say that you start the student rotating, with weights extended, at a rate of one rotation per second. (Of course, this is a very fast rotation rate but using whole numbers makes it easier to understand what is happening.) During a single rotation, the weights will travel a distance of five meters. Their angular velocity is five meters per second. When the weights are brought inward, the rotation rate increases to five times per second, but with a circumference of one meter, the weights are still traveling five meters per second! When the weights go back out, the rotation rate drops but not the angular velocity.

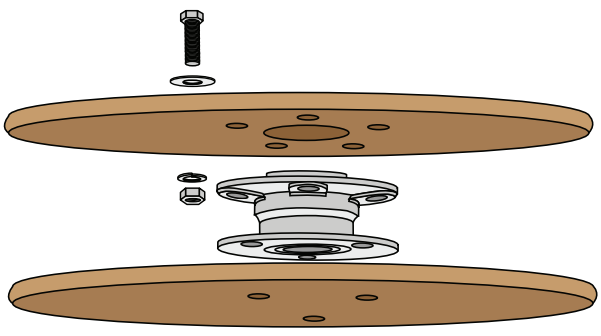
Extensions:

- Obtain videos of Olympic and world championship winter events - figure skating, snowboarding, gymnastics, etc. Have students try to track the center of mass of snowboarder aerials and observe and analyze fast spins on the ice.
- Have students calculate the angular velocity and rotation rate for chair volunteers. They will need a meter stick and a stop watch. Measure the radius of the weights with arms extended and arms brought inward. Calculate the circumference for both radii. Time the rotation rate with arms extended and predict what the rotation rate will be when arms are brought inward.

Procedure: Constructing a bearing platform

By necessity, these instructions will be less than detailed. You will need to obtain a hub bearing from an automotive supply store. The particular bearing will determine the number, size, and length of the bolts needed. Take the picture below to the parts store and have the clerk pick a bearing that most closely matches the illustration.

Pre-cut and sanded wooden disks shown in the illustration are available from a lumber/hardware store. Disks about 16 or 18 inches across are perfect. Three-quarter-inch plywood can also be used. Purchase bolts, washers, and lock washers to match wood thickness and bearing holes. Drill appropriate size holes and assemble. To reduce slipping, glue carpet on the outside surfaces of the wood disks. If this seems like too much for you to do, you probably know someone or there is a parent from the school parent association who can construct the platform for you. The platform will last for years.



Let's Do The Twist

Name: _____

1. Describe what happened when someone twisted in the seat of the swivel office chair. Was the person able to turn the chair around without touching feet to the floor?

   Why or why not? Explain scientifically what took place.

2. What happened when someone tried to move the swivel office chair across the room? Did the chair move from its original position?

   Why or why not? Explain scientifically what took place.

3. Around what point is the chair turning? Explain.

4. Describe what happened when the person rotating in the swivel office chair extended weights outward and then brought them inward?

   Explain scientifically why this happened.

5. Working with group members, create an Olympic acrobatic event for inside the International Space Station. Use the back of this paper to describe your event. Feel free to draw pictures to help visualize the event and the equipment needed.

   - What would the space acrobats do?
   - What equipment would be needed for the event?
   - What aerials could be performed?
   - How would the performance of the athletes be scored?